THE PETROGRAPHY OF SOME QUEENSLAND OIL SHALES.

By A. W. Beasley, M.Sc.,
Department of Geology, University of Queensland.

(Plate XII and Two Text-figures.)

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INTRODUCTION.

"An oil shale is a sapropelic shale rich in organic matter that yields considerable artificial petroleum by distillation" (Twenhofel, 1932, p. 397). Within this definition are included what McKee (1925, p. 27) has called the "true oil shales," as well as the specialised group of algal sapropelic deposits known as the torbanites.

In Queensland such oil shales have been recorded from the Permian, the Jurassic, and the Tertiary. In the Permian three deposits have so far been found—viz., the Alpha, Carnarvon Creek, and Bowen River Coalfield deposits. In the Jurassic small lenses of oil shale have been recorded from some of the Walloon coal-mining areas on the Darling Downs and in the Rosewood-Laidley district. Oil shales have also been recorded from several of the Tertiary basins in the eastern part of the State and, in some of these, the deposits are known to be quite extensive.

No detailed petrographic description of any of these oil shales has previously been published. In fact, laboratory investigations in the past have been confined almost entirely to chemical analyses and distillation tests. This is unfortunate, for the petrological examination of an oil shale is equally as important as its chemical analysis, and is an essential requirement in its systematic study. The quality of an oil shale can, in fact, be determined from a study of its physical properties, since these depend upon the nature, percentages, and arrangement of the various organic and inorganic constituents. A microscopic examination, however, is necessary to determine this data, as well as to investigate the biological origin and the environmental conditions under which the oil shale was formed.

TECHNIQUE IN PREPARATION OF THIN SECTIONS.

For the preparation of thin sections of the oil shales described below the normal procedure in rock sectioning was found to be unsatisfactory, and the following technique had to be developed.

Slices which were cut parallel and at right angles to the bedding (for horizontal and vertical sections) were ground first with 100-hole London Emery, and then with Emery Flour in the ordinary manner. Owing to the soft nature of the oil shales, however, it was necessary to continue grinding in order to remove scratches with a very fine hone held in a sloping position and kept continually wet by playing a thin stream of water upon it. Finally, the surface was given a high polish with Goddard's plate powder, which is also an exceedingly fine abrasive. Then, to avoid harming the material by mounting directly in Canada balsam heated to a high temperature to drive off the volatiles, the Canada balsam was first cooked in the usual way, and allowed to cool. It was then very carefully reheated, and when just remelted the slab was mounted, rather more pressure than usual being applied to squeeze out air bubbles from the viscous balsam. In this way the oil shale was mounted without any damage being done to it. The same method was then followed again in grinding the mounted slab down to the required thinness. As this was of the order of 0·005 mm., considerable care had to be taken during the final grinding. It was also necessary to avoid a high temperature in attaching the cover-slip to the slide, but satisfactory results were obtained by heating at a very low temperature for a prolonged period. Finally, to avoid the possibility of future wrinkling of the very thin section, a flat weight was placed on the cover-slip for several days.

Text-figure 1.—Map showing geographical location of the Alpha, Carnarvon, The Narrows, and Strathpine deposits.

PETROGRAPHIC DESCRIPTIONS.

The oil shales on which the following descriptions are based have all received some official consideration during the war period as possible sources for the production of liquid fuel.

The samples that have been chosen for petrological study are believed to be fairly representative of the various deposits.

ALPHA TORBANITE.

General and Macroscopic.

Locality of sample chosen for study: Tommy Staines Gully, portion 4, parish of Avonmore, county of Drummond, approximately 35 miles S.S.E. of Alpha. Geological Horizon: ? Lower Bowen Series. Age: Lower Permian.

In the hand specimen this is a fine-grained, compact, homogeneous rock of dark brownish-black colour. It has a dull silky lustre, and a sub-conchoidal fracture. It is tough and massive, only indistinct traces of bedding being visible. It is comparatively soft, and gives a yellowish-brown streak. The specific gravity is 1·09. It ignites readily and burns with a bright flame, producing a waxy, aromatic odour.

From the above physical properties the hand specimen is identified as a medium-grade, dull melanocratic torbanite, adopting Dulhunty's (1943) classification.

Microscopic.

(Plate XII, figs. 1, 2.)

Horizontal and vertical sections of this rock have shown that it exhibits a definite microscopic structure. It is made up of translucent algal material, consisting mainly of gelosite and retinosite bodies, separated by films of opaque matrix. Estimations made, using the eye-piece micrometer, of the percentages of gelosite and retinosite present have given an average of 66 per cent. gelosite and 4 per cent. retinosite. This places the rock on the borderline between a medium-grade and high-grade torbanite.

In the vertical section the translucent bodies are elongated in shape, lying parallel to the bedding plane, and in most cases the collapsed central cavity of the algal colonies can clearly be seen. The ratio of length to thickness determined for a large number of these flattened bodies has been found to average about six to one.

In the horizontal section the translucent bodies are roughly rounded in shape, closely packed, and separated by opaque material. They show considerable variation in size, ranging in diameter from about 0·1 to 0·75 mm. Many of them have a series of bulges, which represent simple algal colonies, round their margins, and the bodies in such cases have something of a botryoidal appearance. Unlike spores they do not possess hard and well-defined margins, but tend to fray out into the opaque groundmass.

Apart from the variation in the size of the translucent bodies, the microscopic structure or fabric of the rock is uniform and it is essentially non-banded.

Under ordinary transmitted light the gelosite, which is by far the most abundant maceral in the rock, is pale yellow in colour and almost transparent. It has a low relief with the refractive index very close to that of Canada balsam.

It is anisotropic, and in the vertical section there are positions of extinction parallel and at right angles to the bedding plane, maximum illumination occurring at intermediate positions. In the vertical section it also shows a type of "cross hatching" or rectangular arrangement of polarisation laminae, the laminae appearing when the bedding plane makes an angle of about 27 degrees on either side of the vibration direction of one of the nicols. The angle between these laminae and the bedding plane has been found to be about 70 degrees. As each of the gelosite bodies behaves in a similar manner, they all show their polarisation laminae at the one time in the same direction, giving the effect of optical continuity. This seems to indicate, as Dulhunty (1939, p. 186) has suggested, that the pressure that flattened the translucent bodies parallel to the bedding was responsible for some form of internal strain in the gelosite, giving rise to its polarisation phenomena.

The retinosite is much less abundant than the gelosite. It is orange-yellow in colour and quite distinct from the pale yellow of the gelosite. It is also less transparent than gelosite, and has a slightly higher relief. In all of its other optical properties, however, it is similar to gelosite, and the difference between these two bodies thus is presumably biological rather than the result of varying conditions of preservation.

Both the gelosite and the retinosite bodies have been found to be partly replaced by chalcedony. The grains of chalcedonic silica usually occur in the central part of the bodies and take the form of irregular masses, which are elongate in vertical section and fill the spaces that represent the collapsed central cavities of the algal colonies.

The groundmass of the rock is partly made up of small amounts of the substance which Dulhunty (1939, p. 187) calls "humosite". It is deep brownish-red in colour only in the very thin marginal area of the section, elsewhere appearing quite opaque. It shows no definite habit or internal structure, and is distributed through the matrix in such a way that it seems to have been moulded round the gelosite and retinosite bodies. Unlike gelosite and retinosite it has a high relief and it is isotropic. From the general character and appearance of its irregular particles the humosite seems to be a solidified humic product of decomposition rather than some specific organic material.

Most of the matrix consists, however, of mineral matter to which Dulhunty has given the general name of "matrosite." It is homogeneous and opaque, and consists of very finely-divided clay together with a few very small crystals of pyrites. It forms only a small part of the rock, and in places the skeleton of this matrix becomes discontinuous and fragmentary.

Under a high magnification the gelosite and retinosite bodies show the internal biological structures recently described by Dulhunty (1944, p. 30), from which he concluded that they were fossil forms of a colonial unicellular alga closely related to the living *Botryococcus braunii.*

Chemical Analysis.

A proximate analysis of this sample has given the following result:—

Moisture at 105 deg. C.	1·1 %
Volatile Matter	75·7 %
Fixed Carbon	14·4 %
Ash	8·8 %

Chemically this indicates a good medium-grade to high-grade torbanite. The high percentage of volatiles is due to the large quantity of algal material present, while the low ash content reflects the small amount of mineral matter in the rock. As is the case with all melanocratic torbanites the ratio of volatiles to fixed carbon is less than 10 to 1.

CARNARVON CREEK TORBANITE.

General and Macroscopic.

Locality of sample chosen for study: Outcrop in southern gully on portion 2, parish of Aubrey, county of Consuelo, about half-a-mile east of Carnarvon Creek, approximately 120 miles north of Injune. Geological Horizon: Upper portion of Upper Bowen Series. Age: Upper Permian.

In the hand specimen this is a fine-grained, homogeneous rock of black colour. It cleaves fairly readily along the bedding, and breaks with a hackly fracture. It has a dull lustre and gives a dull greyish-brown streak. The specific gravity is 1·30. Apparently it is resistant to weathering, as the specimen studied shows no evidence of atmospheric weathering more than three millimetres from the exposed surface. It ignites fairly readily and burns with a bright flame, giving a waxy, aromatic odour. Tiny scales of gypsum arranged in small patches occur at intervals along the bedding planes.

From the above physical properties, adopting Dulhunty's (1943) classification, the hand specimen is identified as a low-grade, dull melanocratic torbanite.

Microscopic.

In thin section the rock shows the uniform microscopic structure characteristic of a torbanite. This consists of translucent gelosite and retinosite bodies, separated by films of opaque matrix. The percentages of these translucent bodies in the rock, determined by means of the eyepiece micrometer, have been found to average 42 % gelosite and 3 % retinosite. This places the rock just over the borderline between a low-grade and a medium-grade torbanite.

As in the Alpha torbanite these translucent bodies are disc-shaped, and appear elongated in the vertical section and roughly rounded in the horizontal section. However, they are much smaller in their average size than those of the Alpha torbanite, the diameter of most of them being only 0·15 mm., and there is also much less variation in their size. They have fuzzy, indefinite margins and, in the horizontal section, present a botryoidal appearance.

Under ordinary transmitted light the gelosite is pale yellow in colour, and the retinosite orange-yellow. They both exhibit the characteristic optical properties as described above for the Alpha torbanite. Both the gelosite and the retinosite bodies also have been replaced to a small extent by chalcedony, but the degree of silicification is less than that in the Alpha torbanite.

The groundmass is made up of humosite and matrosite, and is continuous throughout the rock, surrounding the gelosite and retinosite bodies. It is considerably greater in amount than that of the Alpha torbanite.

CHEMICAL ANALYSIS.

A proximate analysis of this sample has given the following result:—

Moisture at 105 deg. C.	3·0 %
Volatile Matter	45·5 %
Fixed Carbon	20·6 %
Ash	30·9 %

Chemically this indicates a low to medium-grade torbanite. As with all melanocratic torbanites the ratio of volatiles to fixed carbon is less than 10 to 1.

THE NARROWS OIL SHALE.

GENERAL AND MACROSCOPIC.

Locality of sample chosen for study: From 225 ft. in Munduran No. 1 Bore, The Narrows. Parish of Rundle, county of Deas Thompson, approximately 20 miles N.N.W. of Gladstone. Geological Horizon: The Narrows Tertiaries. Age: Probably Miocene.

In the hand specimen this is a fine-grained, smooth, even-textured rock of pale greyish-brown colour. It is distinctly laminated, the laminations being quite finely developed. It has a dull lustre and breaks with a hackly fracture. It is soft but moderately tough, and gives a greasy pale brown streak. The specific gravity is 1·56. Thin flakes of the rock ignite with some difficulty when heated with a match and burn with a smoky yellow flame.

From the above description it is apparent that the rock is a low-grade oil shale.

MICROSCOPIC.

(Plate XII, figs. 3, 4.)

Horizontal and vertical sections of this rock have shown that it is made up principally of very finely divided clay, together with a smaller amount of organic material. The clay is intimately associated with some of the organic matter and, under ordinary transmitted light, the whole clay matrix shows a strong yellowish stain. Scattered through this matrix are small, irregularly-shaped, organic masses of a dark reddish-brown colour. This material, which may reasonably be classified as semi-opaque attritus derived from the decay of vascular tissue, makes up about 20 % of the rock. These semi-opaque masses are irregular but generally more or less elongate in shape, and range in length from approximately 0·01 mm. to 0·35 mm., their average length being about 0·05 mm. Presumably the translucent humic attrital material has been macerated to various degrees, some forming the jelly which impregnated and stained the clay matrix. An intensive search has failed to reveal any spores or algal bodies in the thin sections of this oil shale. Most of the organic matter then has come from vascular material.

Within the clay matrix numerous small grains of quartz were recognised. They have not been affected by the yellowish stain, and appear clear and white under ordinary transmitted light. Pyrites is relatively abundant in the rock, occurring both as minute crystals scattered through the matrix and also as fairly large crystals aggregates. Its presence indicates that the original organic ooze was a strongly reducing medium, analogous to the fetid sapropels described from certain modern lakes.

In the vertical section the parallel orientation of the organic masses and the inorganic constitutents in the rock is evident.

From the large amount of mineral matter and the small amount of organic matter seen to be present it is clear that the oil shale is a low-grade one.

Chemical Analysis.

A proximate analysis of this sample has given the following result:—

Moisture at 105 deg. C.	4·8 %
Volatile Matter	29·1 %
Fixed Carbon	3·3 %
Ash	62·8 %

Chemically this indicates a low-grade oil shale. The low percentage of volatiles is determined by the small amount of organic matter present, while the high ash content reflects the large amount of mineral matter in the oil shale.

STRATHPINE OIL SHALE.

General and Macroscopic.

Locality of sample chosen for study: From 70 ft. in Neill's Shaft, Strathpine. Portion 256, parish of Warner, county of Stanley, approximately 14 miles north of Brisbane. Geological Horizon: Petrie Series. Age: Probably Miocene.

In the hand specimen this is a very fine-grained, smooth, even-textured, laminated rock of light brownish-grey colour. It has a dull lustre and breaks with a hackly fracture. It is soft but moderately tough, and gives a greasy brown streak. The speeific gravity is 1·53. Thin flakes of the rock ignite with difficulty and burn for a short time with a smoky yellow flame.

From the above description it is apparent that the rock is a low-grade oil shale.

The presence of mud infillings of the internal cavity of fossil sedges protruding upwards across the laminations of the shale points to shallow water conditions of sedimentation.

Microscopic.

In thin section this rock is seen to be made up principally of very finely-divided clay, with a smaller amount of organic material. The clay is intimately associated with some of the organic matter, and under ordinary transmitted

light the whole clay matrix shows a strong brownish-yellow stain. Scattered through this matrix are small, irregularly-shaped, organic masses of a dark brownish-red colour. This material, which may reasonably be classified as semi-opaque attritus derived from the decay of vascular tissue, makes up from 10 to 15 % of the rock. Some of these organic particles have been found to show good cell structure, particularly in the horizontal section. They vary considerably in size, being never more than 0·4 mm. in length and usually much less. These vascular fragments in the rock are, in fact, in various stages of maceration, and some of them are very nearly opaque. As well as this material a few small, pale yellow, translucent bodies, similar in all respects to the gelosite bodies of torbanite, have been recognised. They appear elongate in the vertical section and roughly rounded in the horizontal one, but they are much more widely spaced than in any torbanite. As gelosite bodies are known to be the fossil form of a colonial, unicellular alga, it is apparent that this oil shale is partly of algal origin. Most of the organic matter in the thin sections, however, is translucent humic matter and brown-opaque attritus. No animal remains were recognised in the thin sections.

A few small grains of quartz and flakes of mica were seen within the clay matrix. They have not been affected by the yellow organic stain and appear clear and white under ordinary transmitted light. Pyrites is quite abundant in the rock, occurring both as very minute crystals scattered through the matrix and also as fairly large aggregates.

In the vertical section the parallel orientation of the organic bodies and the inorganic constituents can clearly be seen.

From the very large amount of mineral matter, and the small amount of organic matter seen to be present, it is apparent that the rock is a low-grade oil shale.

Chemical Analysis.

A proximate analysis of this sample has given the following result:—

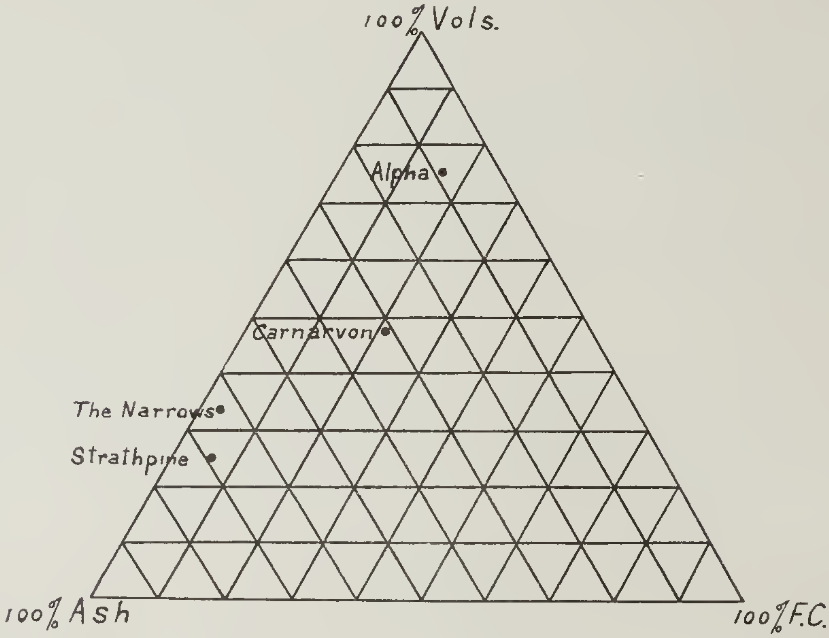
Moisture	6·3 %
Volatile Matter	20·2 %
Fixed Carbon	5·2 %
Ash	68·3 %

Chemically this indicates a low-grade oil shale, which agrees with the determination obtained from the petrological examination of the rock.

CONCLUSION.

From the above descriptions it is clear that the Alpha and the Carnarvon Creek torbanites are very distinct petrologically from The Narrows and the Strathpine oil shales. A striking similarity between the two latter oil shales, however, has become evident. They have been found to be almost identical in macroscopic and microscopic appearance, and in their physical properties. The close petrological relationship between them is also reflected in their

proximate analyses, which are graphically shown on the accompanying text figure together with those of the Alpha and Carnarvon Creek torbanites for purposes of comparison. As recent palaeontological work (Beasley, 1945) has shown that The Narrows Tertiaries and the Petrie Series are both probably of Miocene age, it seems likely that these two Tertiary oil shales were formed at the same time, and they may be correlated with some confidence.



Text-figure 2.—Ternary diagram graphically showing the chemical relationship between The Narrows, Strathpine, Carnarvon Creek and Alpha samples studied.

The two torbanites studied have shown themselves to be generally similar to the Permian torbanites of New South Wales, recently described and classified by Dulhunty (1939; 1943). The medium- to high- grade, dull melanocratic torbanite of the Alpha deposit appears to have precise affinities with the Glen Davis torbanite of New South Wales, while the low-grade, dull melanocratic torbanite of the Carnarvon Creek deposit is the same type as that of Mort's Lower Seam in the Megalong Valley, N.S.W.

ACKNOWLEDGEMENTS.

This work has been financed by the Commonwealth Government Grant through the Council for Scientific and Industrial Research to the University of Queensland. I would like to thank Dr. W. H. Bryan for his helpful criticism, and Professor H. C. Richards for his personal interest in enabling me to carry out this work. I am indebted to Mr. H. G. Dunstan of the Government Chemical Laboratory for the chemical analyses.

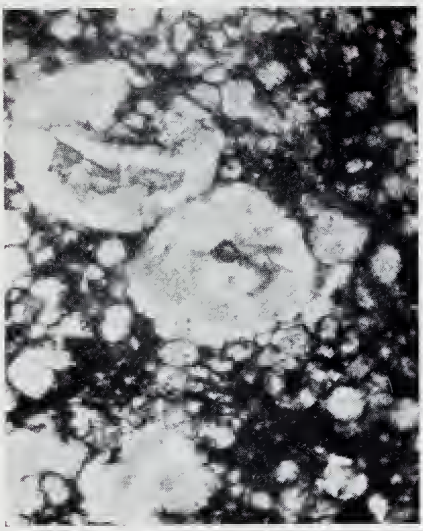


Fig. 1.

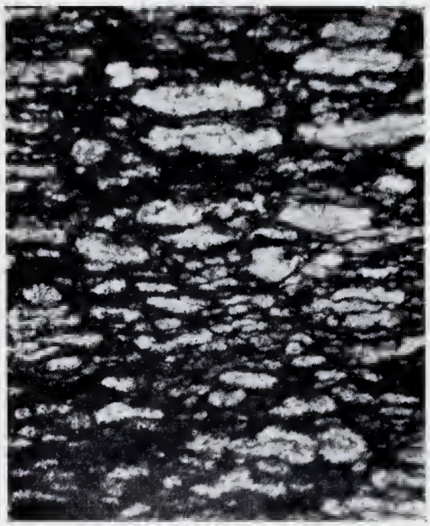


Fig. 2.

Fig. 3.

Fig. 4.

QUEENSLAND OIL SHALES.

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